TREATABILITY STUDY REPORT
Master Metals Site
Cleveland, Ohio

Prepared for:
Master Metals Technical Committee

Prepared by:
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1.0 Introduction

ENTACT, Inc. conducted a treatability study for the Master Metals Technical Committee (MMTC) to obtain information from which to design a stabilization/solidification process that is best suited for treating lead, cadmium, and arsenic contaminated feedstock and soils at the Master Metals Site in Cleveland, Ohio. Based upon information collected during time-critical removal activities, materals present on site contain as much as 155,000 ppm lead. The leachability of the lead in these materials is also very high with TCLP tests performed under the direction of ENTACT showing some levels above 2,000 mg/L. The stabilization/solidification process must reduce the leachability of lead, cadmium, and arsenic to nonhazardous levels. ENTACT performed a bench scale study of treatment alternatives in a manner that replicates the performance of the additives in actual field implementation. The results that are obtained in the laboratory study can be expected for materials that are stabilized in the field.

In addition to rendering the materials nonhazardous, ENTACT directed the treatability study to find the optimum blend of additives which will be most desirable. An important consideration in determining the optimum blend was finding the minimum amount of additive that would successfully treat the on site materials. Optimization of the additive quantities in the blend will reduce the total amount of additives needed for the project. This minimization of additives will also help to prevent a volume increase in the treated material. A substantial cost savings results from using a minimum amount of additive. The reduction in volume of treated material will reduce handling costs as well as disposal and containment costs. ENTACT has developed a patented blend of additives that significantly reduces the leachability of lead and other heavy metals and also minimizes the amount of treatment reagent added to the material. The additives that ENTACT utilizes are very effective. Materials treated with these additives become stable and resist leaching. The additives have a buffering capacity which keeps the treated matrix in a pH range that provides long term durability and reduces the leachability of heavy metal components. These patented additives have been used successfully for treating over 1,000,000 tons of contaminated soil, slag, battery components, and other debris.

2.0 As-Received Material Analysis

In July and August 1997, ENTACT collected twelve sample containers containing representative samples of materials from the Master Metals Site. Samples were collected from the on-site soils, drummed waste and feedstock materials. The matrices were collected according to waste streams found on site in the following classifications:

- gross contamination removed from the concrete slab during remediation activities
- refractory brick and debris drummed on site
- soil contained in roll off boxes
- material originating from furnaces and ball mills
- white lead waste from drums and supersacks in feedstock area
- gray lead powder waste from supersacks in feedstock area
- leaded glass in pallet containers and roll off boxes
- large gray waste pile near furnace building excavated soils from western and southern portions of site
- sample material received on site prior to refining
- by-products of glazing process (roll off boxes)
- drummed solid waste material

These materials were taken to National Environmental Testing Laboratories (NET), of Bartlett, Illinois, for treatability analysis.

Prior to as-received sample analysis, it was determined that materials, being of a heterogeneous nature, would be analyzed as separate waste streams and treated as such. Tests were conducted to determine the total metals concentration and TCLP metals on the one composite sample. These tests established baseline conditions against which treatment additives were evaluated. The results are provided in Table 1.

Total metal concentrations for lead ranged from 12,000 mg/kg to 155,000 mg/kg. As shown in Table 1, all materials exhibited the toxicity characteristic for lead. Toxicity characteristic concentrations for lead ranged from 42.8 mg/L to 2,180 mg/L. Nine of the thiteen waste streams exhibited the toxicity characteristic for cadmium. Toxicity characteristic concentrations for cadmium ranged from less than 0.1 mg/L to 75.3 mg/L. Three of the thirteen waste streams exhibited the toxicity characteristic for arsenic.
Toxicity characteristic concentrations for arsenic ranged from 0.023 mg/L to 15.1 mg/L.

TABLE I

Analysis of Material Samples As-Received

Sample ID	Description	Total Metals Concentration (mg/kg) Pb	Cd	As	TCLP Metals Result (mg/L) Pb	Cd	As
SDY-01	gross surface contamination	89,000	1,500	1,300	1,390	55.5	<2.0
SDY-02	refractory brick	80,000	188	<500	2,180	1.26	15.1
SDY-03	soil-roll off	56,000	89	154	52.0	-	-
SDY-04	furnace/ball mill materials	86,000	3,400	545	42.8	75.3	-
SDY-05	gray powder	75,000	3,440	<500	782	51.2	5.15
SDY-06	white lead powder	70,000	<25	<500	1,210	0.045	8.59
SDY-07	leaded glass	12,000	-	-	177	<0.010	<2.0
SDY-08	dark gray waste pile	48,000	110	180	840	1.38	0.023
SDY-09	on site soil-excavated	17,000	61	220	1,400	3.54	0.0899
SDY-09-2	on site soil-excavated	77,000	68	230	508	2.72	< 2.0
SDY-10	refining samples	84,000	18	430	1,090	< 0.10	< 2.0
SDY-11	glazing by-product	155,000	320	380	1,900	3.86	<2.0
SDY-12	drummed solid waste material	100,000	630	750	620	6.89	<2.0

3.0 Lead Stabilization

Behavior of Lead in Materials

Lead is the primary contaminant of concern at the Master Metals Site due to its ubiquity in feedstock material, waste piles, and surficial soils (see Table 1). Elemental lead (Pb), lead sulfate ($PbSO_4$), lead oxide (PbO), and lead dioxide (PbO_2) are the predominant species found. Sites with carbonate soils generally contain lead carbonate ($PbCO_3$), hydrocerussite ($Pb_3(CO_3)_2(OH)_2$), or lead hillite ($Pb_4SO_4(CO_3)_2(OH)_2$). Other heavy metals, such as antimony, arsenic, cadmium, and copper are sometimes present, but normally at relatively low concentrations (Royer, 1992).

Lead is generally not very mobile in the environment, and tends to remain relatively close to its point of initial deposition. Generally, soils tend to retain lead in the upper few centimeters. The capacity of soil to adsorb lead increases with increasing pH, cation exchange capacity, organic carbon, soil/water Eh (redox potential), and phosphate levels. Lead exhibits a high degree of adsorption on clay-rich soil. Lead compounds can also be adsorbed onto hydrous oxides of iron and manganese and thus be immobilized in salts containing two or more cations (Royer, 1992).

In order for chemical fixation/stabilization to be successful, the various forms of lead salts, especially lead oxide, need to be converted to compounds that are particularly insoluble under the normal pH range. Lead is capable of forming the following three low solubility orthophosphate salts:

$Pb_3(PO_4)_2$,
Pb_2HPO_4 , and
$Pb(H_2PO_4)_2$.

Treatment Technology Description

The stabilization process, sometimes referred to as immobilization or fixation, uses additives to chemically immobilize the hazardous constituents of a contaminated material by combining the additives and lead-bearing matrix within a mixing device. Additive reagents for use in the stabilization of lead contaminated materials include Portland Cement, calcium oxide, calcium carbonate, fly ash, and proprietary additives (EPA, 1989 and Conner, 1990). Other investigators have documented successful stabilization of lead using combinations of the following compounds: magnesium oxide, magnesium hydroxide, reactive calcium carbonates, reactive magnesium carbonates, and boric acid.

ENTACT has developed a proprietary list of additives for stabilizing waste containing lead and other heavy metals including phosphoric acid, monocalcium phosphate (TSP), monoammonium phosphate, and diammonium phosphate either alone or in combination with Portland Cement.

The listed ENTACT patented compounds provide the necessary environment for successful lead stabilization. The first component is a phosphate ion that reacts with metals such as lead to form a salt which is insoluble under normal environmental conditions. The second component is the phosphoric acid buffer system that provides stability to the treated waste mixture under minor environmental changes.

The stabilization process and ENTACT patented additives provide the necessary components for successful stabilization of lead contaminated soil and debris–small and consistent particle size, a phosphate ion, a buffering system, and thorough mixing.

4.0 Additive Design and Selection

All thirteen separate samples, representing the waste streams shown in Table 1, were prepared for treatability testing. The percentages of the additive components used in the blend were varied for several trials. The additive blend varied from two percent to ten percent based upon the matrix characteristics. This relatively wide range of additive mixtures is due in part to the heterogeneous nature of materials present on site. After receiving results from this initial treatability study it was determined that some waste streams required the addition of cement along with the phosphate. These materials were treated with blends of 5% phosphate-5% cement and 5% phosphate-10% cement.

ENTACT's combination of additives is a proprietary blend of chemical agents which greatly reduces the leachability of metals in the stabilized matrix. The leachability of the metals in the treated matrix will be reduced to non-hazardous levels with an appropriate blend of additives. The leachability of treated materials indicates the effectiveness of the various blends. TCLP tests measured the leachability of lead, cadmium, and arsenic from the matrix following treatment.

Selection of Additive Blend

Each of the samples was analyzed separately with an initial additive blend mixture of two (2) percent. This mixture was increased in increments of two (i.e. 4%, 6%, etc.) or a blend of cement/phosphate was utilized until the matrix was rendered nonhazardous. The samples containing the selected blends were tested for TCLP metals. The results of these tests are provided in Table 2. As shown in Table 2, all but two of the waste streams were successfully treated to non-hazardous characteristic levels. The determination was made based on the developing trend for SDY-05 and SDY-10 that the material could not be treated without a substantial addition of additive. Therefore, it was determined that these two waste streams would not be treated on site. Instead, these materials, approximately 10 cubic yards, will be consolidated into roll-off boxes and disposed of as hazardous waste.

Eight of the waste streams were treated successfully with a phosphate treatability of 6-8%. Only three or four waste streams require a treatability blend of phosphate/cement.

ENTACT has used similar additive blends (the same constituents in different proportions) at numerous heavy metal contaminated sites. ENTACT additives offer a very high degree of consistency and reliability resulting in uniform performance characteristics.

Table 2

Analysis of Selected Blends

Sample ID	Treatment	Description	Total Metals (ug/g)			TCLP Metals (mg/L)			soil pH
			Pb	Cd	As	Pb	Cd	As	
SDY-01		**gross surface contamination**	96,000	1,500	1,300	1,390	55.5	<2.0	6.99
	2%	treatment reagent added				1,340	-	-	6.9
	4%	treatment reagent added				577	-	-	6.7
	6%	treatment reagent added				194	-	-	6
	8%	treatment reagent added				114	-	-	-
	5%-5%	treatment blend added				9.36	2.44	<2.0	
	10%-5%	treatment blend added							
SDY-02		**refractory brick**	80,000	188	< 500	2,180	1.26	15.1	7.1
	2%	treatment reagent added				1,050	-	-	6.41
	4%	treatment reagent added				966	-	-	3.92
	6%	treatment reagent added				3.57	-	-	4.32
SDY-03		**roll off boxes of soil/gravel**	56,000	89	154	52	-	-	7.66
	2%	treatment reagent added				1.51	-	-	5.65
	4%	treatment reagent added				1.08	-	-	6.42
	6%	treatment reagent added				0.509	-	-	4.92
SDY-04		**furnace and ball mill material**	86,000	-	-	42.8	75.3	-	7.21
	2%	treatment reagent added				61.9	27.6	-	6.44
	4%	treatment reagent added				49.2	28.8	-	5.22
	6%	treatment reagent added				4.03	10	-	5.71

Table 2

Analysis of Selected Blends

Sample ID	Treatment	Description	Total Metals (ug/g) Pb	Cd	As	TCLP Metals (mg/L) Pb	Cd	As	soil pH
SDY-04-2		furnace and ball mill material	65,000	3,400	-	30.8	130	-	6.44
	8%	treatment reagent added				5.44	31.7	-	-
	15%	treatment reagent added				2.01	1.97	1.59	4.57
	10%-5%	treatment blend added				< 0.80	< 0.050	< 2.0	10.01
SDY-05		**gray powder (supersacks)**	75,000	-	-	782	51.2	5.15	6.55
	2%	treatment reagent added				557	-	-	6.49
	4%	treatment reagent added				537	-	-	6.42
	6%	treatment reagent added				530	-	-	6.45
SDY-06		**white powder (drums & supersacks)**	70,000	< 25	< 500	1,210	0.045	8.59	11.38
	2%	treatment reagent added				27.7	-	-	12
	4%	treatment reagent added				5.4	-	-	11.57
	6%	treatment reagent added				1.42	-	-	9.96
SDY-07		**lead glass material**	12,000	-	-	1.26	<0.10	<2.0	5.67
	2%	treatment reagent added				16.2	-	-	3.25
	4%	treatment reagent added				< 0.800	-	-	2.85
	6%	treatment reagent added				3.28	-	-	2.95
	8%	treatment reagent added				4.27	-	-	-
SDY-08		**dark gray waste pile**	48,000	110	180	840	1.38	0.0226	6.78

Table 2

Analysis of Selected Blends

Sample ID	Treatment	Description	Total Metals (ug/g) Pb	Cd	As	TCLP Metals (mg/L) Pb	Cd	As	soil pH
	2%	treatment reagent added				900	4.09	-	-
	4%	treatment reagent added				4.34	0.286	-	-
	6%	treatment reagent added				1.42	0.172	-	-
SDY-09		**excavated soil from on site**	17,000	61	220	1400	3.54	0.0899	6.17
	4%	treatment reagent added				877	1.47	-	-
	6%	treatment reagent added				408	1.32	-	-
	8%	treatment reagent added				45.8	1.11	-	-
SDY-09-2		excavated soil from on site	77,000	68	230	508	2.72	< 2.0	5.22
	2%	treatment reagent added				18.9	-	-	5.53
	4%	treatment reagent added				1.59	-	-	5.64
	6%	treatment reagent added				4.06	-	-	5.02
SDY-10		**composite of 2 gal sample buckets**	84,000	18	430	1,090	< 0.10	< 2.0	8.92
	6%	treatment reagent added				961	-	-	7.68
	8%	treatment reagent added				556	-	-	6.51
	10%	treatment reagent added				356	-	-	6.17
SDY-11		**roll off boxes of glazing by-product**	155,000	320	380	1,900	3.86	<2.0	7.04
	10%	treatment reagent added				122	2.29	< 2.0	5.06
	5%-5%	treatment blend added				92	1.95	<2.0	8.84

Table 2

Analysis of Selected Blends

Sample ID	Treatment	Description	Total Metals (ug/g) Pb	Cd	As	TCLP Metals (mg/L) Pb	Cd	As	soil pH
	10%-5%	treatment blend added				9.64	<0.050	<2.0	11.14
SDY-12		**solid drummed material (dross, etc)**	100,000	630	750	620	6.89	<2.0	6.19
	10%	treatment reagent added				293	4.86	<2.0	6.92
	5%-5%	treatment blend added				110	0.19	<2.0	7.7
	10%-5%	treatment blended added				0.125	0.022	<2.0	9.15

5.0 Conclusions

ENTACT's selected blends of additives were successful in stabilizing the lead contaminated materials in eleven of the thirteen waste streams present at the Master Metals Site. The average TCLP level for lead was reduced from approximately 922 mg/L, to about 3 mg/L, a reduction of more than 99.6%. A similar reduction in TCLP levels for cadmium (98.1%) and arsenic developed from the addition of the cement to the treatability samples. Based upon total metals results, materials on site with like lead concentrations may be mixed prior to treatment to consolidate waste streams and provide effective processing of the waste materials and treatability reagents.

Two blends of additive will be utilized to treat contaminated material at the Master Metals Site - phosphate blend and phosphate/cement blend. The chosen blends of additives met all requirements of the treatability study. The blends result in a minimal addition of material to the contaminated waste stream which will help prevent a volume increase after compaction in the final disposal location. The durability of the final remedy is assured over the long term as a result of the pH buffering capacity of the additives. The ENTACT blend offers better performance for the requirements of land disposal of contaminated materials as compared with other additives.

6.0 References

1. "Handbook Stabilization Technologies for RCRA Corrective Actions," (EPA/625/6-91/026) United States Environmental Protection Agency, Office of Research and Development, Washington, DC, August 1991.

2. Royer, Michael D., Ari Selvakumar and Roger Gaire. "Control Technologies for Remediation of Contaminated Soil and Waste Deposits at Superfund Lead Battery Recycling Sites," J Air Waste Management Association, Volume 42, Number 7, pp. 970-980 (1992)

3. Conner, Jessie R., Chemical Fixation and Solidification of Hazardous Waste, Van Nostrend Reinhold (1990).